Effect of Early and Late Planting on Sunflower Performance in the Southeastern United States

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Abstract. Sunflower hybrids (*Helianthus annuus* L.) which mature in fewer than 100 days can facilitate double cropping in the humid subtropic climatic area of the United States (which has >210 frost free days and 1.2 m or 47 in. annual rainfall) and in other countries with similar climates. Little information is available for the very early or very late planting dates needed for this strategy. From 1981 to 1984 sunflowers were grown as a double crop either before soybean [*Glycine max* (L.) *Merrill*] or after corn (*Zea mays* L.). Yield and oil content of hybrids declined only slightly by delaying planting from mid-March to late April, but yield and oil content declined sharply with delayed planting from 7 August to 2 September. Flowering interval was planting-date dependent and was estimated shortest for planting dates near the summer solstice. Yields were not satisfactory for plantings after 18 August. Supplemental irrigation and early desiccation did not affect yield. Bird damage was significant if harvesting was not prompt. Yield and oil production potential of sunflower was very good for the planting dates before 18 August, suggesting a good potential for double cropping with sunflower in this climatic zone.

Introduction

Current sunflower (*Helianthus annuus* L.) production worldwide occurs predominantly in mid-latitude and humid continental climates [2], especially the latter. The potential for using sunflower in systems that produce more than one agronomic crop per year (double or multiple cropping) is generally limited to warm areas with long growing seasons, such as the southern United States. This climatic area corresponds to the humid subtropic climate zone which also occurs in significant continental areas of eastern south-central South America (Paraguay, Uruguay, and parts of Brazil and Argentina), southern China, and the eastern coastal areas of Australia.

The humid tropic zone of the southern U.S. has more than 210 frost-free days each growing season [22]. Much of the future increase in southern U.S. production is predicted to result from introducing new double cropping alternatives [5]. Double cropping in early spring or late summer in the southern states is facilitated by relatively high seasonal totals of incoming radiation and rainfall and milder temperatures, compared to the northern latitudes during comparable periods.

The predominant soils of the southern states are Ultisols, which typically have only minor or no herbicide carryover problems from crop to crop. This is particularly true of the sandier soils of the Atlantic and Gulf Coastal Plains. Long idle periods after corn (*Zea mays* L.) or before soybean [*Glycine max* (L.) *Merrill*] with traditional monocropping leave soils exposed to erosive, high-intensity seasonal rainfalls [18]. The conventional choices of double-crop species have been limited to small grains, planted in the fall. Small grains are slow to develop crop canopies that protect the soil from erosion. In many parts of the South, fall planting of a small grain generally limits the next year's warm season crop to late-planted soybean. Unger et al. [21], in the Texas High Plains, double cropped sunflower after winter wheat (*Triticum aestivum* L.) and vice versa with greater success than with a sorghum (*Sorghum bicolor*)/wheat system. We recognized that with proper management, using early-maturing hybrids, sunflower could be double cropped after corn or ahead of soybean. Date of

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Table 1. Corrected yield (kg/ha) by location and planting date @ 9% moisture for oil and non-oil hybrids

Location	Florence																
Year	1981			1982					1983					1984			
Dates	8/17	8/26	9/2	3/12	4/6	5/1	8/17	8/26	5/2	5/10	8/11	8/18	8/29	3/20	4/17	4/27	8/7
Non-oil Hybrids																	
D 131				3256	3164	2378	1554	739	2696	2256	1172	476	705	1594	2072	1988	924
Sunbird				2965	3487	2671	1493	389	2724	2387	1235	524	360				
IS 924														1630	1966	1507	1425
Oil Hybrids																	
CAR 205	1521	169	—	2305	2111	1527	1283	131									
CAR 206				2476	1875	1667	704	—									
DO 164									2829	2276	1515	921	708	1330	2170	1889	1217
DO 705				2505	2476	1802	1120	339	2260	1931	1350	1050	637				
DO 844	1691	996	265	2415	2772	2344	1514	577	2576	2194	1690	1142	685				
DO 855														1596	2210	1739	1236
HySun 101	1510	952	301	2456	2443	1464	1338	319									
IS 3001														1196	1672	1003	941
IS 7000														1245	1644	1440	1248
IS 7101														1387	1490	1279	1407
IS 7116														1203	1446	1234	1076
MCF 605														1697	1650	1081	1074
MCF 610	1563	330	—	2784	2378	1688	1460	128	2460	2009	1690	756	339				
MCF 700	1164	789	151	2475	2628	1737	1362	389	2201	1700	1560	999	520				
PAGSF 101	1535	250	—	2569	1872	1497	1208	145	2414	1939	1196	902	432				
PAGSF 102									2480	1897	1416	1101	—				
SH 01481				—	—	—	1429	487	2375	2155	1326	1133	781	983	1450	922	1178
SH 24906				—	—	—	1499	402	2608	2595	1541	838	749	1289	1991	1405	1381
TRI 448																	1002
TRI 549																	1283
TRI566DW																	894

Location	Blackville		Charleston	
Year	1984		1984	
Dates	3/23	4/18	3/16	5/1
Non-oil Hybrids				
D 131	2005	1968	1342	1910
Sunbird				
IS 924	2005	1915	915	1911
Oil Hybrids				
CAR 205				
CAR 206				
DO 164	1791	1587	1268	1762
DO 705				
DO 844				
DO 855	1721	1626	1276	1403
HySun 101				
IS 3001	1836	1806	1293	1611
IS 7000	1913	1823	1044	1539
IS 7101	1764	1677	2085	1058
IS 7116	1579	1764	1495	1418
MCF 605	1753	1769	2064	1414
MCF 610				
MCF 700				
PAGSF 101				
PAGSF 102				
SH 01481				
SH 24906				
TRI 448				
TRI 549				
TRI566DW				

planting studies were established to assess the yield and quality of sunflower hybrids planted very early or very late in the season to accommodate a double cropping strategy in the humid subtropics.

Materials and Methods

Experiments were conducted in the spring and late summer at the Coastal Plains Soil and Water Conservation Research Center in Florence, South Carolina, from 1981 through 1984, and at the USDA Vegetable Laboratory in Charleston, South Carolina, and the Clemson University Edisto Experiment Station at Blackville, South Carolina, in early spring 1984. Sunflower was planted in late winter through early spring during the traditional corn planting period, and in late summer in the period immediately following the traditional corn harvesting period. Soils at the three sites were: Florence, Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudult); Charleston, Hockley loamy fine sand (fine-loamy, siliceous, thermic Plinthic Paleudalf); and Blackville, Orangeburg loamy sand (fine-loamy, siliceous thermic Typic Paleudult).

Sunflower was sown into fields that had been planted the previous year or earlier the same year to corn. In the case of late summer sunflower plantings, corn had been planted in spring, harvested late in July, and stover disked immediately prior to planting sunflower in early August. Field preparation for sunflower in all cases included two to three diskings. Weed control was with preplant incorporation of 0.70 kg AI/ha* Treflan†, (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) and 2.8 kg AI/ha Amiben (3-amino-2,5-dichlorobenzoic acid). Beginning in spring 1984 Amiben was no longer used, substituting instead 3.4 kg AI/ha Lasso (2-chloro-2–6 ft diethyl-N-(methoxymethyl) acetanilide).

Lime was applied at all sites at 455 kg/ha $CaCO_3$ equivalent in spring only. Late summer plantings were limed in the preceding crop.

Fertilization at Florence and Charleston was 225 kg N/ha, 85 kg P_2O_5/ha, and 170 kg K_2O/ha broadcast and incorporated before planting. Fertilization at Blackville was 70 kg N/ha, 50 kg P_2O_5/ha, and 100 kg K_2O/ha preplant incorporated and followed by side dressing with 67.4 kg N/ha at the V–8 growth stage [16]. These rates were used (in the absence of a standard soil test recommendation for sunflower in South Carolina) to insure adequate fertility on these highly infertile Paleudult soils following corn which had been fertilized to soil test levels.

Hybirds were planted in Florence and Blackville using cones on John Deere 71 flexi-planters attached to tool bars with in-row subsoilers which disrupted subsoil compaction immediately ahead of the planters. Subsoil shanks penetrated to 45 cm**. Subsoilers were not used in Charleston. Hybrids are given in Table 1. Some variation in plot dimensions occurred from season to season. In all cases, however, plots had at least 4 rows (on 76 cm spacings at Florence, 96 cm at Blackville and 1.0 m at Charleston, which are the standard row-crop spacings for each of these production areas). In all cases rows were at least 11 m long, and at least 7.7 m of the two center rows (15.4 m of total row length) were harvested for yield determination. Sunflower was planted to stands of approximately 100,000 plants/ha†† and thinned before reaching the V–6 growth stage to 75–88,000 plants/ha in irrigated plots and to 63,000 plants/ha in non-irrigated plots.

Statistical designs varied slightly from season to season. In all cases hybrids were planted in either three or four replicates in a randomized complete block design. The experiment was split in 1982 and 1983 to determine effects of irrigation and in 1983 to determine effects of pre-harvest chemical desiccation with foliar application late in the R8 growth stage of a 30% N urea ammonium nitrate (UAN) solution at 145 l/ha rate*. For the irrigated studies, variety main plots were randomly split for irrigation or absence of irrigation. Irrigation was primarily for stress avoidance and was not systematically scheduled. One irrigation was applied in 1984 to all spring-planted plots. Irrigations are depicted in Figure 1. For the dessication studies, half the experiment was foliar treated in a split block design. Upon analysis of variance, neither irrigation nor dessication splits significantly affected yield or oil content, and these treatments were subsequently pooled for further analysis. Regression analysis included limited data from plots in an adjacent tillage study treated identically but providing additional dates of planting. Plots were cultivated once or twice as needed before plants reached 40 cm height.

Dates of 50% flowering (R5.1 growth stage) were noted. Plots were hand harvested as soon as feasible after physiological maturity. Number of heads harvested were recorded for measurement of final stand. Seed was removed from heads using a small-plot thrasher. Fractional area of bird damage for each harvested head was noted for calculating corrected ("undamaged") yield estimates. Corrected yields were determined by using the ratio of damaged area to total area of heads (yield loss) to upwardly adjust individual plot yields as follows: corrected yield = yield ÷ (1 − yield loss). Debris and low test-weight seed were removed through air-cleaning before weighing seed for yield. Seed moisture content was determined instrumentally on 200 gram subsamples and yields were adjusted to a 9% seed moisture basis. Weight

* kg/ha can be converted to lbs/A by multiplying kg/ha by 0.893.

† Company and trade names are shown for the benefit of the reader and do not imply endorsement or preferential treatment by the United States Department of Agriculture.

** To convert cm to inches, divide cm by 2.54. 100 cm = 1 meter (m).

†† 1 hectare (ha) = 2.47 acres (A).

* To convert l/ha to gallons/A multiply l/ha by 0.107.

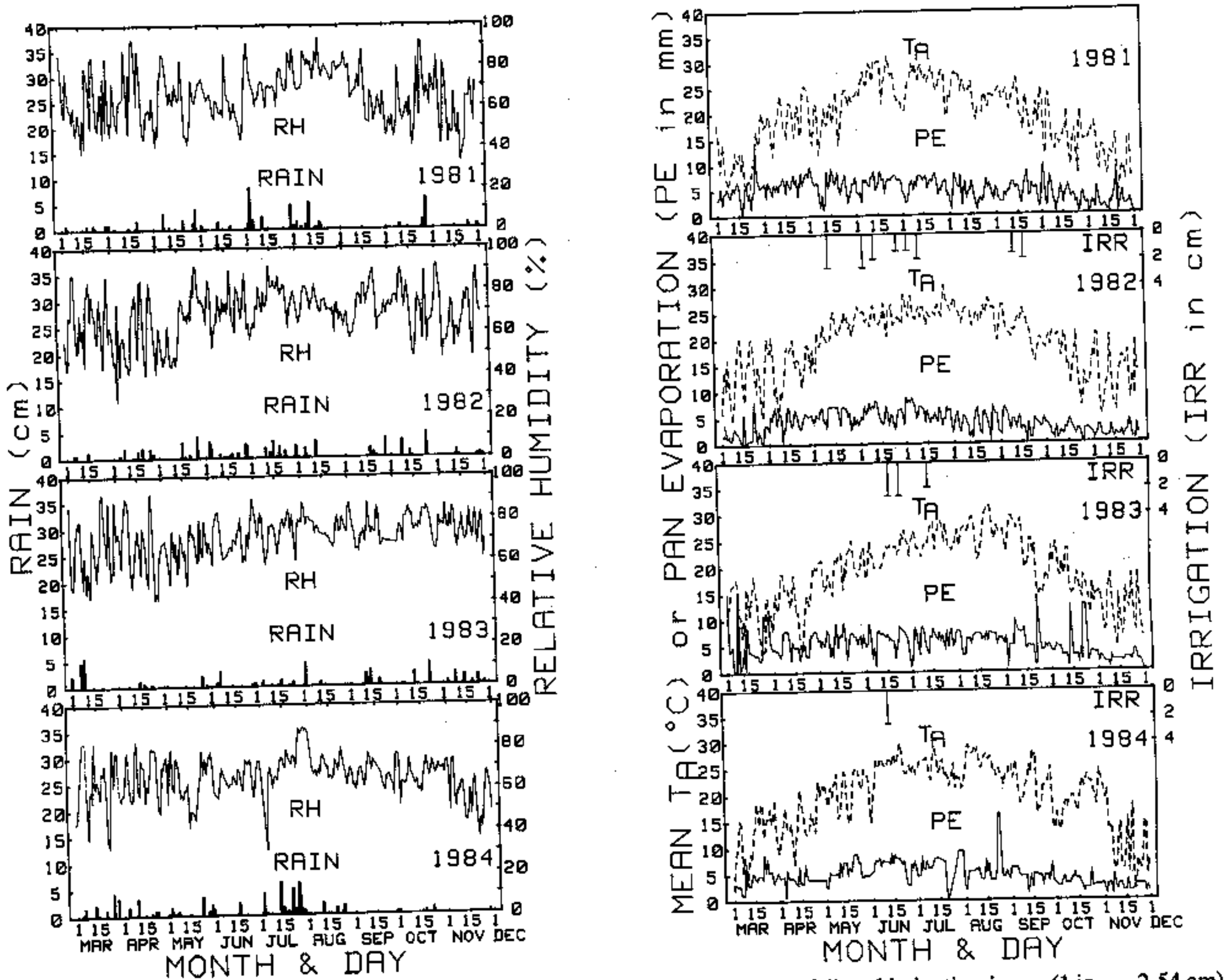

Fig. 1. Daily meteorological data for the growing seasons of 1981–84 with rainfall and irrigation in cm (1 in. = 2.54 cm), % relative humidity, pan evaporation in mm (1 in. = 25.4 mm), and ambient temperature in °C (°F = °C[9/5] + 32).

of seed was determined on 100-seed samples. Oil content was determined on oil hybrids using methods described earlier [10]. Rainfall, relative humidity, ambient temperature, and pan evaporation at Florence were recorded at an automated weather station within 0.5 km of the experimental sites. All sunflower was planted in soils brought to or near field capacity at planting by rainfall or pre-irrigation.

Results and Discussion

Variation in seasonal weather over the 1981 to 1984 period was typical of the physiographic region (Fig. 1). A significant meteorological pattern distinguishes the growing seasons that result from spring planting versus late summer planting. Planting in spring provides a growing season characterized by increasing temperature, day length, and potential evapotranspiration. Opposite conditions prevail for late summer planting. In each year temperature and rainfall patterns generally favored spring planting over late summer planting, although in no year did fall temperatures preclude production of acceptable yields if planting occurred on or before 18 August (Table 1), thereby permitting flowering and seedfill before frost.

Spring planted oil hybrids generally yielded over 2000 kg/ha and yields of non-oil hybrids were over 2500 kg/ha in 1982 and 1983. Yields for spring plantings declined in 1984 but were still at commercially acceptable levels (>1000 kg/ha). Late summer planted sunflowers yielded well over 1000 kg/ha all years if planted on or before 18 August. In South Carolina, a double-cropping scheme following corn would allow 3–4 weeks between corn harvest and sunflower planting (becoming more favorable in states farther south, particularly along coastal areas). Because of the unpredictability of

Table 2. Population mean of corrected yield (kg/ha), bird damage (%), seed wt (g/100 seed), raw yield (kg/ha), and days to flowering (days) by location and date for non-oil types

Location	Florence													
Year	1982					1983					1984			
Dates	3/12	4/6	5/1	8/17	8/26	5/2	5/10	8/11	8/18	8/29	3/20	4/17	4/27	8/7
Parameter														
Corr. yield	3110	3325	2525	1524	564	2710	2322	1204	500	533	1612	2019	1748	1225
Bird damage	1.8	2.0	0.1	1.7	0.8	0.8	1.1	9.2	21.3	8.3	20.6	7.9	6.7	18.0
Seed wt.	9.67	8.65	5.98	6.37	5.67	8.78	8.19	9.07	9.74	6.26	9.88	8.94	7.92	8.23
Raw yield	3055	3258	2523	1499	559	2688	2297	1114	417	495	1370	1882	1624	1038
Days to flowering	76.5	64.8	55.6	56.3	71.3	58.3	54.4	57.7	58.0	68.8	80.2	63.3	57.8	55.5
Prob. > F		Date	Hybrid	DXH			Date	Hybrid	DXH			Date	Hybrid	DXH
Corr. yield		0.0001	NS	NS			0.0001	NS	0.0227			0.0799	NS	NS
Bird damage		NS	NS	NS			0.0001	0.0463	NS			0.0029	NS	NS
Seed wt.		0.0001	0.0001	0.0014			0.0001	0.0007	NS			0.0152	NS	NS
Raw yield		0.0001	NS	0.0736			0.0001	NS	0.0395			0.0147	NS	NS
Days to flowering		0.0001	0.0003	NS			0.0001	0.0001	0.0005			0.0001	0.0001	0.0142
5% LSD														
Corr. yield		347	205				310	94				496	366	
Bird damage		1.4	1.1				7.4	4.5				9.9	5.9	
Seed wt.		0.71	0.45				0.97	0.57				0.82	0.87	
Raw yield		344	190				305	94				455	311	
Days to flowering		2.6	1.5				1.2	0.6				1.3	1.0	

Location	Blackville		Charleston	
Year	1984		1984	
Dates	3/23	4/18	3/16	5/1
Parameter				
Corr. yield	2005	1942	1129	1910
Bird damage	0.7	1.2	0	8.2
Seed wt.	7.85	8.49	9.20	10.58
Raw yield	1991	1913	1129	1769
Days to flowering	—	—	—	—

Prob. > F	Date	Hybrid	DXH	Date	Hybrid	DXH
Corr. yield	NS	NS	NS	NS	NS	NS
Bird damage	NS	0.0686	NS	0.0053	NS	NS
Seed wt.	0.1054	NS	NS	NS	NS	NS
Raw yield	NS	NS	NS	NS	NS	NS
Days to flowering	—	—	—	—	—	—
5% LSD						
Corr. Yield	588	186		709	1245	
Bird damage	1.7	1.3		3.6	4.1	
Seed wt.	1.13	.86		2.82	2.90	
Raw yield	612	177		723	1288	
Days to flowering	—	—		—	—	

Table 3. Population mean of corrected yield (kg/ha), % oil (g/100), oil production (kg/ha), bird damage (%), seed wt (g/100 seed), raw yield (kg/ha), and days to flowering (days) by location and date for oil types

Location	Florence							
Year	1981			1982				
Dates	8/17	8/26	9/2	3/12	4/6	5/1	8/17	8/26
Parameter								
Corr. Yield	1497	581	239	2498	2319	1716	1292	379
% Oil	37.8	32.9	11.5	42.9	43.5	35.0	35.2	34.1
Oil Prod.	567	200	58	1075	1011	605	456	135
Bird Damage	0.0	0.0	0.0	2.8	2.5	4.7	1.4	2.0
Seed wt.	3.86	2.65	—	4.86	3.94	2.61	3.77	3.33
Raw yield	1497	581	239	2426	2263	1648	1273	371
Days to Flowering	62.6	66.1	67.9	78.6	66.4	55.6	58.3	72.7
Prob. > F	Date	Hybrid	DXH		Date	Hybrid	DXH	
Corr. Yield	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	
% Oil	0.0001	0.0057	0.0030		0.0001	0.0001	0.0057	
Oil Prod.	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	
Bird Damage	—	—	—		0.0001	0.0021	NS	
Seed wt.	0.0001	0.0001	0.0567		0.0001	0.0001	0.0001	
Raw yield	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	
Days to Flowering	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	
5% LSD								
Corr. Yield	311	141			206	161		
% Oil	11.7	4.7			1.1	1.4		
Oil Prod.	129	59			94	75		
Bird Damage	—	—			1.6	1.8		
Seed wt.	0.42	0.41			0.37	0.26		
Raw yield	311	141			207	157		
Days to Flowering	1.00	0.96			2.42	0.98		

Location	Florence								
Year	1983					1984			
Dates	5/2	5/10	8/11	8/18	8/29	3/20	4/17	4/27	8/7
Parameter									
Corr. Yield	2467	2007	1476	983	627	1325	1747	1333	1153
% Oil	41.0	38.8	39.9	38.1	33.8	43.0	45.9	43.8	44.8
Oil Prod.	1012	810	590	374	213	577	805	586	516
Bird Damage	1.7	3.3	6.2	17.0	24.4	19.9	19.4	39.9	14.0
Seed wt.	4.76	4.15	5.65	5.40	3.34	5.01	4.17	3.84	4.56
Raw yield	2426	2011	1395	859	511	1109	1501	999	1012
Days to Flowering	57.1	53.1	57.8	58.7	70.2	81.0	63.9	57.0	54.5
Prob. > F		Date	Hybrid	DXH		Date	Hybrid	DXH	
Corr. Yield		0.0001	0.0001	0.0004		0.0001	0.0024	NS	
% Oil		0.0001	0.0001	0.0001		0.0001	0.0001	0.0007	
Oil Prod.		0.0001	0.0001	0.0001		0.0001	0.0026	NS	
Bird Damage		0.0001	0.0025	0.0001		0.0001	0.0797	NS	
Seed wt.		0.0001	0.0001	NS		0.0001	0.0001	0.0001	
Raw yield		0.0001	0.0001	0.0002		0.0001	0.0009	NS	
Days to Flowering		0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	
5% LSD									
Corr. Yield		152	141			207	418		
% Oil		1.8	0.7			1.82	2.33		
Oil Prod.		65	61			104	197		
Bird Damage		5.4	3.9			5.9	11.3		
Seed wt.		0.49	0.26			0.26	0.52		
Raw yield		148	137			181	391		
Days to Flowering		0.72	0.76			0.63	1.06		

Table 3. Continued.

Location	Blackville			Charleston		
Year	1984			1984		
Dates	3/23	4/18		3/16	5/1	
Parameter						
Corr. Yield	1765	1722		1504	1442	
% Oil	43.2	50.3		47.6	48.0	
Oil Prod.	761	867		719	693	
Bird Damage	0.3	6.7		0.2	25.0	
Seed wt.	4.17	4.40		5.84	5.64	
Raw yield	1760	1618		1500	1164	
Days to Flowering	—	—		—	—	
Prob. > F	Date	Hybrid	DXH	Date	Hybrid	DXH
Corr. Yield	NS	NS	NS	NS	NS	0.0370
% Oil	0.0001	0.0063	NS	NS	NS	NS
Oil Prod.	0.0061	NS	NS	NS	NS	0.0193
Bird Damage	0.0001	NS	NS	0.0001	0.0499	0.0781
Seed wt.	0.0816	0.0001	NS	NS	0.0001	NS
Raw yield	0.0262	NS	NS	0.0129	NS	0.0257
Days to Flowering	—	—	—	—	—	—
5% LSD						
Corr. Yield	357	242		676	519	
% Oil	1.66	2.74		2.78	5.17	
Oil Prod.	185	137		332	260	
Bird Damage	4.4	1.9		11.3	11.2	
Seed wt.	0.73	0.49		0.45	0.83	
Raw yield	393	231		686	492	
Days to Flowering	—	—		—	—	

precipitation in these studies, supplemental irrigation did not affect yield or oil content. In several instances, irrigation was followed soon by unexpected rainfall. In these instances leaching of applied fertilizer and root aeration problems were likely to have occurred.

Planting in the early spring until about 1 May or in mid-summer until about 18 August with these short-season hybrids (Tables 2 and 3) resulted in flowering before the onset of insect pests (early-spring planting) or after major insect activity (mid-summer planting) since nights were rapidly cooling. Similarly these periods correspond to the two annual periods of lowest relative humidity in the region which probably contributed to the near absence of disease in the experimental plots throughout the study. Disease was noted only once during the study. In 1982, the 12 March planting of hybrid DO 844 suffered Alternaria damage on approximately 20% of the plants from irrigated plots. All plantings attracted a lively assortment of insects but none were identified as being detrimental to sunflower and careful inspection of heads, seeds, and stalks never revealed evidence of insect damage. Minimization of insect or disease problems through adherence to these planting dates has been generally confirmed by extensive studies at Blackville, South Carolina.†

Oil content (Table 3) was acceptable for nearly all dates of planting reported but was generally 5–10 percentage poins higher for early-spring than for late-summer planting dates. As with yield, oil contents became generally unacceptable for plantings after 18 August.

The quality of oils was intensively investigated for the 1982 season. Sunflower oil fatty acid composition depends on the mean low temperature from flowering to seed maturity [1, 9, 12]. Robertson et al. [11] showed that oleic acid content is positively correlated ($r = 0.87$) and that linoleic acid content is negatively correlated ($r = -0.83$) with the average minimum low temperature from flowering to harvest. This trend was seen in the fatty acid composition of the 1982 plantings [7]. Spring

† Personal communication Dewitt T. Gooden, Edisto Experiment Station, Blackville, South Carolina.

plantings resulted in an oleic acid content of 41%–49% which was equal to or slightly higher than the linoleic acid content of 41%–49%. August plantings resulted in a linoleic acid content ranging from 62%–76%. Oleic acid ranged from 12%–18%. Oils high in oleic acid are used for commercial snack-food frying while high linoleic acid oils are used for polyunsaturated products such as margarine and salad dressings.

One of the most severe production problems in these studies was bird depredation (Tables 2 and 3). No bird damage was experienced in 1981, but the problem became increasingly severe in later years. The local bird population appeared to become conditioned to the presence of sunflowers in a given field. Moving experimental fields seasonally partially alleviated the problem by delaying the onset of full scale feeding; but by far the only effective measure was depredation avoidance via the promptest possible harvesting at maturity. There was no statistically significant correlation between bird damage and either planting date or flowering intervals. The experience with bird damage prompted experimentation in 1983 with application of foliar applied UAN at physiological maturity to accelerate harvest. In these studies, UAN applied as a desiccant accelerated drying by only 1 or 2 days, and had no effect on yield or oil content. Use of distress-imitating noise-makers proved useless. These observations were paralleled by grower observations in the Savannah River valley. Use of bird repellant chemical sprays was not investigated. It is likely that with larger production acreages the bird problem could prove devastating for some growers in some years, particularly when conditions of dim light (cloudiness or misting) prevail, which favor feeding while simultaneously delaying harvest. These conditions often occur for prolonged periods in the humid south, especially in late fall and winter.

Weight of 100 seeds (Tables 2 and 3) varied considerably over the 4 years of study although the variation did not consistenly coincide with seasonal factors. In 1981, 100 seed weights of mid-summer planted sunflower were low, which may have been related to the late-summer drought and early onset of cool weather that summer and fall. In 1982, the 100 seed weight of spring planted flowers steadily declined and was followed for the 1 May planting by a relatively wet period. Seed weights of oil types were higher again for the midsummer plantings. Weight of 100 seeds for the 2 May 1983 planting was 182% and 146% greater for oil and non-oil types respectively from 1 May planted values from

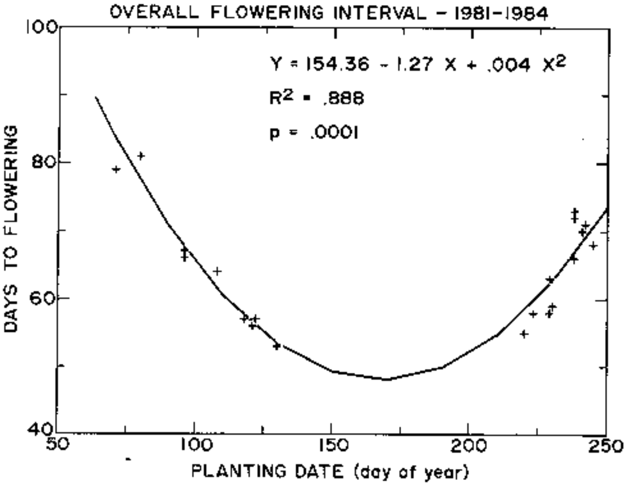

Fig. 2. The flowering interval (date of 50% flowering minus date of planting) of the trial collection in days, as a function of planting date.

the previous year. This occurred despite irrigating in half of all plots in spring of both 1982 and 1983 (irrigation had no significant effect). There was no correlation between 100 seed weight and either date of planting or flowering interval.

A major factor influencing yield, quality, and cultural efficacy of sunflower in the humid south is the planting date dependency of the flowering interval (Fig. 2). In spring, the number of days to flowering declined to a predicted minimum on the summer solstice (day 172), after which the number of days to flowering increased with delayed planting. The general impact of delayed planting was to reduce yield, oil content, and oil production (yield × oil fraction) of oil hybrids, as seen in Figure 3. The ever shortening maturity period in spring appeared to defeat the increasing daily interval available for photosynthesis and heat unit accumulation, resulting in a "trend" toward lower oil hybrid yield ($P = 0.32$) and lower oil content ($P = 0.31$). Correlations of spring oil hybrid yield or oil content with date of planting were good in each individual year (mean $R^2 = 0.911$; mean $P = 0.132$) but variability of the spring data between years reduced the reliability of the relationships when the 3 years' data were pooled. Individual yearly correlations and the trend of the combined data indicated declining yield and oil content with delayed planting in spring, but within a range that is less critical for financial success than is the case for late summer planted sunflower. Starting in summer, time to maturity increases, but shorter days and cooler temperatures (especially at night) occur during the critical seed filling period and again yields decrease with de-

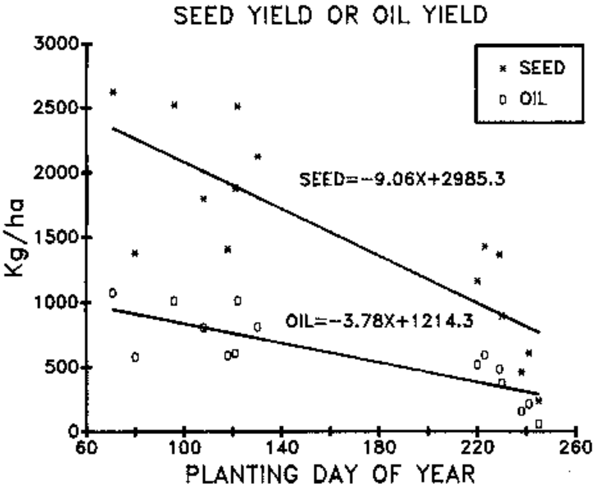

Fig. 3. Mean oil hybrid seed yield and oil production in kilograms per hectare (lbs/A = kg/ha × 0.893) as a function of planting date. R^2 equals 0.657 and 0.666, respectively.

layed planting. Late-summer planted oil hybrid yields in kg/ha = 13309.1−53.4 X, where X is planting day of year, R^2 = 0.743, and P = 0.0006. Essentially the same effect occurs with regard to oil accumulation. Late-summer planted percent oil content = 161.6−0.54 X, where X is planting day of year, R^2 = 0.803 and P = 0.0002. The effect of season on the individual parameters of oil content and yield, which both decline with delayed planting, is accentuated with respect to oil production (the product of yield and oil content).

Robinson [15] reported that planting dates in southern latitudes lag those in northern latitudes. Early planting has usually resulted in higher yields and oil contents than late plantings in areas where the sunflower growing season is greatly affected by low spring and low fall temperatures [6, 8, 14, 20]. And it has been shown that early planting will slow flowering [19]. However, these data are from areas where extreme seasonal fluctuations in mean daily temperatures occur during the same seasonal intervals studied in this experiment. As Figure 1 illustrates, there is a seasonal correspondence in mean daily temperature and day length; these temperature changes are small, however, compared to those from the same periods for the Dakota-Minnesota region or Texas high plains. Data from Garside [3] also show performance responses to February through August variation in planting date in semiarid tropical Australia despite favorable temperatures over the entire planting period. Goyne and Schneiter [4] showed a variation in both the nature and intensity of photoperiod dependency among sunflower genotypes. Robinson et al. [13] concluded that temperatures and day length dependency are difficult to separate in the field, providing a potent interactive regulation of phenologic expression. In this study their combined effect minimized flowering interval as planting dates neared the solstice.

The limited data from Blackville and Charleston suggest that yield potential and oil production are good at both locations. Generally the climate becomes progressively milder going from Florence to Blackville to Charleston due to the increased coastal climatic influence which reaches inland up the Savannah River valley. The fact that yields in Charleston were lower than in Blackville, and more similar to yields in Florence, may relate to the lack of subsoiling at Charleston. Subsequent research has shown a substantial sunflower yield benefit on Coastal Plain soils of this one practice alone [17]. Subsoiling of these soils has been particularly beneficial where supplemental irrigation is not available (as was the case at both Blackville and Charleston).

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